DEVELOPING DEVICE, PROCESS CARTRIDGE AND IMAGE FORMING APPARATUS

FIELD OF THE INVENTION AND RELATED ART:

The present invention relates to a developing device, a process cartridge and an image forming apparatus, wherein an electrostatic latent image is formed through an electrophotographic process, and then is developed into a visual image with a developer contained in a developing device.

Here, the electrophotographic image forming apparatus is an apparatus which forms an image on a recording material through an electrophotographic process. The electrophotographic image forming apparatus may be an electrophotographic copying machine, an electrophotographic printer (a LED printer, a laser beam printer or the like), an electrophotographic printer type facsimile machine, an electrophotographic printer type word processor or the like.

The process cartridge is a cartridge containing as a unit an electrophotographic photosensitive drum and a charge member, a developing member or a cleaning member, the unit being detachably mountable to the main assembly of the image forming apparatus. The process cartridge is a cartridge containing as a unit an electrophotographic

photosensitive drum and at least one of a charge member, a developing member and a cleaning member, the unit being detachably mountable to the main assembly of the image forming apparatus. The process cartridge may contain as a unit an electrophotographic photosensitive drum and at least a developing member, the unit being detachably mountable to a main assembly of the electrophotographic image forming apparatus.

In an electrophotographic image forming apparatus using the electrophotographic image forming process, use has been made with the process cartridge type in which the process cartridge comprises as a unit the electrophotographic photosensitive member and process means actable on the electrophotographic photosensitive member, the unit being detachably mountable to the main assembly of the electrophotographic image forming apparatus. With the use of the process cartridge type, the maintenance operation can be carried out in effect by the users without necessity of relying on serviceman, and therefore, the operativity is improved. Therefore, the process cartridge type is widely used in the field of electrophotographic image forming apparatus.

With the electrophotographic image forming apparatus of such a process cartridge type, the user exchanges the cartridge by himself or herself. The therefore, there is provided a developer amount

detecting means by which the shortage of the developer in the process cartridge is notified to the user.

As an conventional example of the developer amount detecting means, there is a type in which two electrode rods are provided in the developer container of the developing means, and a change in the part between the two electrode rods to detect the presence or absence of the developer. This is called "yes-or-no type". Various systems of this type have been put into practice.

Recently, it is desired that the remaining amount of the developer is detected continuously or substantially real-time (real-time or containers type) is provided. With this type, the remaining amount of the developer can be notified to the user substantially real-time to facilitate exchanging of the process cartridge.

SUMMARY OF THE INVENTION:

Accordingly, it is a principal object of the present invention to provide a developing device, a process cartridge and an electrophotographic image forming apparatus wherein the remaining amount of the developer can be detected substantially real-time.

It is another object of the present invention to provide a developing device, a process cartridge and a an electrophotographic image forming apparatus

wherein the remaining amount of the developer can be detected with precision.

According to an aspect of the present invention, there is provided an electrophotographic image forming apparatus, a process cartridge and a developing device for developing an electrostatic latent image formed on an electrophotographic photosensitive member, said developing device being usable with a main assembly of an electrophotograhic image forming apparatus, said developing device comprising; a developing member for supplying a developer to the electrophotographic photosensitive member for developing the electrostatic latent image formed on said electrophotographic photosensitive member; a first electrode provided opposed to developing member; a second electrode disposed such that at least a lower end thereof takes a position lower than said first electrode when said developing device is mounted to the main assembly of the electrophotographic image forming apparatus; wherein an electric signal is generated in accordance with an electrostatic capacity between said first electrode and second electrode when said first electrode or second electrode is supplied with a voltage from the main assembly of said electrophotographic image forming apparatus, and is measured by the main assembly of the electrophotographic image forming

apparatus to detect a remaining amount of the developer.

These and other objects, features, and advantages of the present invention will become more apparent upon consideration of the following description of the preferred embodiments of the present invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of an electrophotographic image forming apparatus according to an embodiment of the present invention.

Figure 2 is an outer perspective view of an electrophotographic image forming apparatus according to an embodiment of the present invention.

Figure 3 is a longitudinal sectional view of a process cartridge according to an embodiment of the present invention.

Figure 4 is an outer perspective view of a process cartridge according to an embodiment of the present invention, as seen from bottom.

Figure 5 is an outer perspective view of a mounting portion of a main assembly of the apparatus for mounting the process cartridge.

Figure 6 shows an arrangement of first and

second electrodes and a recess in a developer amount detecting means according to an embodiment of the present invention.

Figure 7 is an illustration of a positional relationship between the reduction of the amount of the developer and the first and second electrodes with the consumption of the developer.

Figure 8 shows a relationship between the amount of the toner and electrostatic capacity in the developer amount detecting means according to an embodiment of the present invention, wherein (a) shows a normal state, (b) too much developer in the recess, (c) too long period of time required for the developer to enter the recess.

Figure 9 shows an example in which the second electrodes is cut so as not to be opposed to the recess.

Figure 10 is a perspective view of first and second electrodes according to an embodiment of the present invention.

Figure 11 is a perspective view of first and second electrodes according to another embodiment of the present invention.

Figure 12 is a longitudinal sectional view of a process cartridge according to another embodiment of the present invention.

Figure 13 is a longitudinal sectional view

of a process cartridge according to a further embodiment of the present invention.

Figure 14 is a perspective view of first and second electrodes disposed in a developer chamber according to another embodiment of the present invention.

Figure 15 is a perspective view of first and second electrodes disposed in a developer chamber according to a further embodiment of the present invention.

Figure 16 shows an electric circuit for first and second electrodes and a developing roller.

Figures 17 illustrates changes in the amount of the toner and the electrostatic capacity (a) when a developing member is not used as a capacitor, (b) when it is used as a capacitor.

Figure 18 shows a state in which the developer is present only adjacent a developing blade.

Figure 19 is a longitudinal sectional view of a major part of a extended bent portion of the second electrodes.

Figure 20 shows an electric circuit for the developer amount detecting divides according to an embodiment of the present invention.

Figure 21 shows an example of display of the amount of the remaining developer.

Figure 22 shows another example of display

of the amount of the remaining developer.

Figure 23 shows a further example of display of the amount of the remaining developer.

Figure 24 is a longitudinal sectional view of a further example of display of the amount of the remaining developer.

Figure 25 is a constitutional sectional view of a major part of the developer amount detecting means of Figure 24 in which an intermediary electrode is provided.

Figure 26 illustrates the developer and a bottle electrode when the amount of the developer in a developer chamber is decreasing.

Figure 27 shows a relationship between the amount of the toner and an electrostatic capacity in the developer amount detecting device of Figure 24.

Figure 28 shows a relationship between the amount of the toner and an electrostatic capacity in the developer amount detecting device of Figure 24 with the intermediary electrode.

Figure 29 is a longitudinal sectional view of a major part of a developer amount detecting means according to a further embodiment of the present invention.

Figure 30 shows relationships between the toner amount and an electrostatic capacity in the developer amount detecting divides of each of Figures

19, 24 and 29.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a developing apparatus, a process cartridge, and an electrophotographic image forming apparatus, which are in accordance with the present invention, will be described with reference to the appended drawings.

Embodiment 1

First, referring to Figures 1 - 3, an example of an electrophotographic image forming apparatus in which a process cartridge structured in accordance with the present invention is removably mountable will be described. In this embodiment, the electrophotographic image forming apparatus is an electrophotographic laser beam printer A, and forms an image on recording medium, for example, recording paper, OHP sheet, fabric, and the like, with the use of an electrophotographic image formation process.

The laser beam printer A has an electrophotographic photosensitive member in the form of a drum, that is, a photosensitive drum 7. The photosensitive drum 7 is charged by a charge roller 8 as a charging means, and the charged photosensitive drum 7 is exposed to the laser beam projected in accordance with image formation data, from an optical means 1, as an electrostatic latent image forming

means, which has a semiconductor laser 1a as a light source, a rotational polygonal mirror 1c rotated by a scanner motor 1b, and a reflection mirror 1d. As a result, a latent image in accordance with the image formation data is formed on the photosensitive drum 7. This latent image is developed into a visible image, or a toner image, by a developing means 9.

More specifically, the developing means 9 has a development chamber 9A equipped with a development roller 9a as a developing member, and a developer container 11, as a developer holding portion. The developer container 11 is located next to the development chamber 9A, and contains a developer stirring-conveying member 9b (developer stirring means). As the developer stirring member 9b is rotated, developer T is sent to the developer roller 9a in the development chamber 9A. In the development chamber 9, a developer stirring member 9e is positioned adjacent to the development roller 9a, and circulates the developer through the development chamber 9A. The developer T used in this embodiment is magnetic developer.

The development roller 9a contains a stationary magnet 9c. As the development roller 9a is rotated, the developer is borne on the development roller 9a and is carried in the rotational direction of the development roller 9a. As the development

roller 9a is further rotated, the developer on the development roller 9a is give triboelectrical charge by the development blade 9d while being formed into a developer layer with a predetermined thickness, and then is supplied to the development region of the photosensitive drum 7. As the developer is supplied to the development region, it is transferred onto the latent image on the photosensitive drum 7, forming a toner image. The development roller 9a is electrically connected to a development bias circuit, which applies development bias voltage to the development roller 9a. Normally, the development bias voltage is compound voltage composed of AC voltage and DC voltage, to the development roller 9a.

Meanwhile, a recording medium 2, for example, a piece of ordinary paper, having been placed in a sheet feeder cassette 3a, is conveyed to a transfer station by a pickup roller 3b, conveyer roller pairs 3c and 3d, and a registration roller pair 3e, in synchronism with the formation of the tone image. In the transfer station, a transfer roller 4 as a transferring means is positioned. As voltage is applied to the transfer roller 4, the toner image on the photosensitive drum 7 is transferred onto the recording medium 2.

After the transfer of the toner image onto the recording medium 2, the recording medium 2 is

conveyed to a fixing means 5 by a conveyance guide 3f. The fixing means 5 has a driver roller 5c and a fixing roller 5b. The fixing roller 5b contains a heater 5a. As the recording medium 2 is passed through the fixing means 5, the fixing means 5 fixes the unfixed toner image on the recording medium 2 to the recording medium 2 by the application of heat and pressure.

Thereafter, the recording medium is conveyed further, and is discharged into a delivery tray 6, through a reversing path 3j, by discharge roller pairs 3g, 3y, and 3i. The delivery tray 6 is located on top the main assembly 14 of the laser beam printer A, that is, an electrophotographic image forming apparatus. The pointing direction of a pivotal flapper 3k may be switched to discharge the recording medium 2 by a discharge roller pair 8m without passing the recording medium 2 through the reversing path 3j. In this embodiment, the aforementioned pickup roller 3b, conveyer roller pairs 3c and 3d, registration roller pair 3c, conveyance guide 3f, discharger roller pairs 3g, 3h, and 3i, and discharge roller pair 3m, constitute a conveying means.

Referring to Figure 3, in this embodiment, a process cartridge B is assembled in the following manner. First, the developer container 11 (developer holding portion) which has the developer stirring-conveying member 9b and holds developer, and the

development chamber 9A which holds the developing means 9, are welded together to form a development unit, and then, the thus formed development unit is joined with a cleaning means container 13 in which the photosensitive drum 7, a cleaning means 10 comprising cleaning blade 10a and the like, and the charge roller 8, are attached. Incidentally, the developing means 9 comprises the development roller 9a, development blade 9d, and the like.

The process cartridge B is removably mounted by a user into a cartridge mounting means provided in the main assembly 14 of the electrophotographic image forming apparatus, in the direction indicated by an arrow mark X. In this embodiment, the cartridge mounting means comprises a pair of guiding means 13R and 13L (unillustrated), and a pair of guiding portions 16R and 16L (unillustrated). The guiding means 13R are located, one for one, on the external surfaces of the end walls located at the longitudinal ends of the process cartridge B, as shown in Figure 4, and the guiding portions 16R and 16L, into which the guiding means 13R and 13L are insertable, one for one, are provided on the apparatus main assembly side, as shown in Figure 5.

According to the present invention, the process cartridge B is provided with a developer amount detecting apparatus capable of continuously

(substantially real-time) detecting the amount of the developer remaining in the developer container 11, as the developer is consumed.

Referring to Figure 6, according this embodiment, the developer amount detecting apparatus is provided with first and second electrodes 81 and 82, between which a recess 80 is present. The recess 80 opens downward in a manner to allow developer to enter the recess 80 after developer is sent thereto by the developer stirring-conveying member 9b. Further, the electrodes 81 and 82 are placed approximately in parallel to the development roller 9a and also approximately in a manner to oppose each other. In other words, in terms of the direction perpendicular to the direction in which the developer T is moved by the developer stirring-conveying member 9b (stirring member), the first electrode 81 is located at a position different from the position where the second electrode 82 is located. The first and second electrodes 81 and 82 are attached to a portion 12 of the process cartridge frame (hereinafter, "frame portion 12"), which constitutes the wall of the development chamber 9A. More specific structural arrangements of the electrodes 81 and 82 will be described later in detail.

The developer amount is detected by applying AC voltage to either the first or second electrodes 81

and 82 and measuring the electrical signals generated in accordance with the electrostatic capacity between the electrodes 81 and 82.

Next, the movement of the developer, and the manner in which the amount of the developer reduces, will be described, starting from a point in time prior to the shipment of the process cartridge, through the period in which the developer in a process cartridge is consumed after the mounting of the process cartridge into the main assembly 14 of the electrophotographic image forming apparatus.

Referring to Figure 3, prior to the shipment of a process cartridge, a seal 30 for sealing the developer container 11 is pasted between the development chamber 9A and developer container 11, as indicated by the dotted line in Figure 3, so that the developer is prevented from leaking outward due to the vibrations or the like which occur as the process cartridge is transported.

When a user uses a brand-new process cartridge, the user is to mount the process cartridge into the electrophotographic image forming apparatus main assembly 14 after removing the seal 30. Some of the recent electrophotographic image forming apparatuses, however, are structured so that the seal 30 is automatically removed after the mounting of a process cartridge into the electrophotographic image

forming apparatus main assembly 14.

As described previously, the developer stirring-conveying member 9b is provided in the developer container 11. The developer stirring-conveying member 9b comprises a stirring shaft 9b1, and an elastic sheet 9bs (Mylar) attached to the stirring shaft 9b1. The developer within the developer container 11 is conveyed into the development chamber 9A by the rotation of the developer stirring-conveying member 9b. In this embodiment, the developer stirring-conveying member 9b rotates once in every four seconds.

Due to the function of the developer stirring-conveying member 9b, the developer is instantly sent into the development chamber 9A, smoothly readying the image forming apparatus for an image forming operation, even when the process cartridge B is used for the first time, that is, even immediately after the seal 30 is removed. Almost at the same time as the developer is sent into the development chamber 9A, it is also sent into the space between the first and second electrodes 81 and 82, changing the electrostatic capacity between the two electrodes.

There are the following four forces which affect the distribution of the developer in the adjacencies of the first and second electrodes 81 and

82:

(1) upward force which affects the developer as the developer is sent into the development chamber 9A by the developer stirring-conveying member 9b;

(2) downward force which generates due to the self-weight of the developer;

(3) force which works against the downward force (when a large amount of developer is present under the recess 80, it functions as a lid which covers the recess 80 from below, preventing the self-weight of the developer from causing the developer to descend from within the recess 80;

(4) force which results from the lowness of the fluidity of the developer itself and works in a manner to hold the developer at its current position.

When there is a sufficient amount of developer within the developer container 11 and development chamber 9A, the force (1) is extremely large, and the force (3) works as the lid for the recess 80, keeping the developer in the recess 80 confined in the recess 80; in other words, a state in which developer remains packed between the first and second electrodes 81 and 82 is maintained, and therefore, a high electrostatic capacity value is continuously shown.

As the usage of the process cartridge B continues, the amount of the developer in the

adjacencies of the development roller 9a reduces due to the developer consumption for development. However, the adjacencies of the development roller 9a is continuously replenished with the developer from the developer container 11 by the function of the developer stirring-conveying member 9b. Thus, with the continuous usage of the process cartridge B, the amount of the developer within the developer container 11 reduces, and the top surface of the developer mass within the developer container 11 descends.

Referring to Figure 7, as the top surface of the developer mass within the developer container 11 descends in the order indicated by Figures 7(a), 7(b), 7(c), and 7(d), the forces (1) and (3) reduce, allowing the amount of the developer between the first and second electrodes 81 and 82 to gradually reduces. As a result, the electrostatic capacity between the two electrodes changes.

Describing further Figure 7, Figure 7(a) shows a state of the interior of the developer container 11 when a sufficient amount of developer is present in the developer container 11, and the first and second electrodes 81 and 82 are within the developer mass. Figure 7(b) shows a state of the interior of the developer container 11 when the amount of the developer within the developer container 11 has slightly reduced, and the top surface of the developer

mass within the developer container 11 has descended to the same level as those of the bottom and top ends of the first and second electrodes 81 and 82, respectively. Figure 7(c) shows the a state of the interior of the developer container 11 when the amount of the developer has further reduced to a level at which there is no developer in the recess 80, and the surface of the developer mass within the developer container 11 has dropped below the level of the bottom end of the first electrode 81, being approximately at the level of the center of the second electrode 82. Figure 7(d) shows a state of the interior of the developer container 11 when the amount of the developer in the developer container 11 has reduced to a level at which the top surface of the developer mass within the developer container 11 barely touches the bottom end of the second electrode 82.

The manner in which the electrostatic capacity value between the two electrodes 81 and 82 changes in response to the of the surface of the developer mass position (amount of developer remainder) within the developer container 11 is affected by the fluidity of the developer in use and the conveying performance of the developer stirring-conveying member 9b.

For example, when the developer has such fluidity as that of water, the position of the top

surface of the developer mass in the developer container 11 perfectly coincides with the position of the top surface of the developer mass between the first and second electrodes 81 and 82. However, the actual fluidity of the developer is far lower than the fluidity of water, and therefore, even after a certain amount of the developer was conveyed into the development chamber 9A by the developer stirring-conveying member 9b, the top surface of the developer mass remains as it was prior to the conveyance of the developer into the development chamber 9A. Therefore, the position of the top surface of the developer mass between the first and second electrodes 81 and 82 also tends to change slightly behind the change in the position of the top surface of the developer mass in the developer container 11 as shown by Figures 7(a) - 7(d).

The manner in which developer enters between the first and second electrodes 81 and 82 is affected by the performance of the developer stirring-conveying member 9b. In other words, if the conveying performance of the developer stirring-conveying member 9b is either excessively strong or excessively weak, the relationship between the change in the amount of the developer in the developer container 11 and the change in the value of the electrostatic capacity between the two electrodes 81 and 82 deviates.

Therefore, the positions and shapes of the first and second electrodes 81 and 82 must be optimized according to the fluidity of the developer and the developer conveyance performance of the developer stirring-conveying member 9b.

As described above, the electrostatic capacity between the first and second electrodes 81 and 82 changes in response to the developer distribution in the regions which affect the sensitivities of the first and second electrodes, that is, the toner distribution in the recess 80 and adjacencies thereof. However, the developer within the recess 80 remains under the above described various forces (1) - (4), and therefore, there is a tendency that the value of the electrostatic capacity does not stabilize until the aforementioned four forces reach virtual equilibrium. In other words, the value of this electrostatic capacity between the two electrodes 81 and 82 shows some deviations if the developer temporarily enters the aforementioned regions by an excessively amount, or if the entrance of the developer into the aforementioned regions lags.

The graph in Figure 8 shows the relationship between the amount of the developer remaining in the adjacencies of the first and second electrodes 81 and 82, and the corresponding electrostatic capacity

between the first and second electrodes 81 and 82, during a period in which a given amount of developer was supplied to the adjacencies of the two electrodes 81 and 82 and was completely consumed. Figure 8(b) shows a case in which an excessive amount of developer entered the regions in which the amount of developer affects the sensitivities of the first and second electrodes 81 and 82, and Figure 8(c) shows a case in which the developer entrance into the above described regions lagged. Figure 8(a) shows the normal case, or the normal changes.

When an excessive amount of developer entered the aforementioned particular regions, the electrostatic capacity value suddenly increased as represented by a point indicated by a referential code p in Figure 8(b), whereas when the developer entrance into the regions lagged, it took a certain length of time for the electrostatic capacity value to reach its equilibrium level as represented by a range indicated by a referential code q in Figure 8(c).

One of the means for solving this problem is to reduce the dimension of the recess 80 in terms of the direction in which developer is conveyed; more specifically, the dimension of the recess 80 in terms of the developer conveyance direction should be reduced by shortening the first electrode 81, that is, the electrode having a greater distance from the

development roller 9a, in such a manner that the position of the bottom end of the first electrode 81 moves upward. However, if the first electrode 81 is shortened by more than a certain length, the surface area of the condenser made up of the first and second electrodes 81 and 82 becomes too small to provide the condenser with a satisfactory amount of sensitivity. Therefore, the electrode 81 requires a proper length.

On the other hand, if the second electrode 82, that is, the electrode having a shorter distance from the development roller 9a, is extended so that its top end reach the level of the top end of the recess 80, the distance between the first and second electrodes 81 and 82 within the recess 80 becomes too small, that is, small enough to raise the sensitivity of the aforementioned condenser to a level at which the condenser is capable of detecting the aforementioned fluctuation of the electrostatic capacity value, which occurs while the state of developer mass becomes stabilized. Therefore, the developer amount may not be accurately detected. Thus, it is not desirable to extends the second electrode 82 in the manner described above.

Referring to Figure 9, the sensitivity of the aforementioned condenser to the electrostatic capacity can be controlled by shortening the second electrode 82 itself by cutting off the portion of the second

electrode 82 corresponding to the recess 80, more specifically, by shortening the second electrode 82 so that the position of the top end of the second electrode 82 falls below the level of the bottom end of the first electrode 81, in other words, so that after the proper mounting of the process cartridge B or the developing apparatus 9 into the electrophotographic image forming apparatus main assembly, at least the bottom end of the second electrode 82 would be below the level of the first electrode 81. Incidentally, the excessive shortening of the second electrode 82 creates a problem, that is, insufficient sensitivity. Therefore, the second electrode 82 must be cut to a proper length. In this embodiment, the first and second electrodes 81 and 82 are in the form of a plate, and the dimension of the first electrode 81 in terms of the direction perpendicular to the longitudinal direction of the development roller 9a is greater than that of the second electrode 82.

In addition to the detecting method employing the above described structural arrangement, there are other detecting methods; for example, if a process cartridge is provided with a recording means, it is possible to record print count, duration of process cartridge, and the like, so that the detection can be started for the first time after the elapsing of a

certain length of time which is thought to be needed for the aforementioned equilibrium to be realized.

It is desired to improve the accuracy with which the developer remainder amount is continuously detected is to increase the amount of the change in the electrostatic capacity. More specifically, this objective can be accomplished by increasing the surface areas of the first and second electrodes 81 and 82, by reducing the distance between the first and second electrodes 81 and 82, and/or by the like methods. In order to increase the surface areas of the electrodes, the electrodes may be corrugated as shown in Figure 10, or may be dimpled as shown in Figure 11.

Incidentally, if restrictions in cartridge design make it impossible to secure a space large enough for such electrodes as those described above, or if it is necessary to reduce process cartridge cost, one of the first and second electrodes 81 and 82 may be formed of a piece of round rod as shown in Figures 12 and 13.

Next, referring to Figures 14 and 15, positioning of the electrodes in terms of the longitudinal direction of the developer roller 9a will be described.

Referring to Figure 14, the detection accuracy can be improved by making the dimensions of

the first and second electrodes 81 and 82 in terms of the longitudinal direction of the developer roller 9a virtually the same as the dimension of the image forming region in terms of the longitudinal. However, if the detection accuracy is less essential, electrodes smaller in dimension in terms of the longitudinal direction of the development roller 9a may be placed across the center or end portion of the image forming region to reduce the cost. In such a case, however, it is impossible to detect the developer distribution in terms of the longitudinal direction of the development roller 9a, and therefore, in order to compensate for such a problem, it is desired that a plurality of electrodes smaller in the dimension in terms of the longitudinal direction of development roller 9a are strategically distributed across the image forming region, for example, at both ends, center, and the like, as shown in Figure 15.

As image formation continues, developer consumption progresses. Eventually, the developer between the longitudinal edge of the development blade 9d for regulating the developer amount on the peripheral surface of the development roller 9a, and the second electrode 82, that is, the developer between the development roller 9a and second electrode 82, is consumed, and thereafter, images with abnormal white spots are produced, signaling the developer

depletion, or "no developer condition".

The accuracy with which the developer level below which an image with abnormal white spots is produced is detected, can be drastically improved by electrically connecting the development roller 9a in such a manner as to create another condenser in which the development roller 9a functions as one of the electrodes (counterpart is the second electrode 82) and which is connected in parallel to the aforementioned condenser constituted of the first and second electrodes 81 and 82, as shown in Figure 16.

Figure 17 shows typical changes in electrostatic capacity; Figures 17(b) and 17(a) show the cases in which the development roller 9a was caused to, and not caused to, double as one of the condenser electrodes, respectively. It is evident that the magnitude of the change in the electrostatic capacity, which occurs in response to the change (amount of consumption) in the amount of toner in terms of toner unit as the developer remainder amount nearly reduces to the level at which the formation of an image with abnormal white spots begins, was far greater, in other words, the detection accuracy was far better, in the case represented by Figure 17(b) than that in the case represented by Figure 17(a).

The reason for the occurrence of a larger change in the electrostatic capacity relative to the

change (consumption) in the toner amount in terms of toner unit, immediately before the beginning of the period in which images with abnormal white spots, is that the abnormal white spots begin to be created as the amount of the toner on the peripheral surface of the development roller 9a begins to decrease. Therefore, measuring the amount of the developer on the peripheral surface of the development roller 9a as accurately as possible is one of the essential requirements for improving the detection accuracy.

It becomes possible to raise "detection sensitivity" in the adjacencies of the development roller 9a by making the above described structural arrangement, in which the development roller 9a is made to double as one of the pair of electrodes in the aforementioned second condenser, while placing the second electrode 82, which functions as the counterpart to the development roller 9a, in the adjacencies of the development roller 9a. The difference in detection accuracy between Figures 17(a) and 17(b) was created by such a structural arrangement.

Further, in order to improve the accuracy with which the threshold developer level below which images with abnormal white spots are produced, it is necessary to improve "detection sensitivity" in the adjacencies of the peripheral surface of the

development roller 9a.

Even when there is almost no developer on the peripheral surface of the development roller 9a, development is possible as long as developer is present in the adjacencies of the development blade 9d as is represented by the developer T in Figure 18. Therefore, the accuracy, with which the threshold developer level below which images with abnormal white spots is detected, can be improved by improving the sensitivity with which the developer T in the above described region is detected.

Thus, in this embodiment, a third electrode 83 was provided, which was placed close to the longitudinal edge of the development blade 9d and extended in parallel to the development roller 9a as shown in Figure 19. More specifically, the third electrode 83 was added as an extension of the second electrode 82, being bent toward the development blade 9d. As a result, the accuracy with which the threshold developer level was detected was further improved.

The above described third electrode 83 does not need to be a part of the second electrode 82. In other words, even if the third electrode 83 is independent from the second electrode 82, it does not matter as far as the threshold developer level detection accuracy is concerned. In such a case, the

third electrode 83 may be constituted of a piece of round rod in stead of a piece of metallic plate.

Further, when the third electrode 83 (portion angled relative to electrode 82) is formed as an electrode independent from the second electrode 82, there is a possibility that not only is the third electrode 83 used as a part of the means for continuously detecting developer remainder amount, but also can be used as a part of a means for highly accurately detecting the presence (absence) of developer.

As described above, the developer amount in the development chamber 9A is estimated by measuring the developer amount between the first and second electrodes 81 and 82, and the developer amount between the first and second electrode 81 and 82 can be measured by continuously detecting the electrostatic capacity between the first and second electrodes 81 and 82.

Further, the accuracy with which the threshold developer level below which images with abnormal white spots are formed is detected can be improved by providing the third electrode 83 as an integral part of the second electrode 82 and using the development roller 9a as the counterpart to the third electrode 83 which makes up the additional condenser with the development roller 9a.

In order to detect the developer remainder amount from the early stage of process cartridge usage, it is necessary to place a detecting means on the developer container side. On the other hand, in order to accurately detect the threshold developer level below which images with abnormal white spots are produced, it is necessary to place a detecting means in the adjacencies of the development roller 9a. Being able to satisfy these two mutually contradicting requirements with the provision of only a single detecting means characterizes this embodiment of the present invention. In other words, according to this embodiment, a detecting means is placed in the adjacencies of the development roller in such a manner that the detecting means is enabled to sense the change in the height of the developer mass. In other words, one of the essential characteristics of the process cartridge structure in this embodiment is that the developer amount within the developer container can be determined on the basis of the information regarding the developer sent by the developer stirring-conveying member 9b from the developer container 11.

The provision of the above described structure made it possible to continuously detect the developer remainder amount while maintaining a high degree of accuracy in detecting the threshold

developer level below which images with abnormal white spots are produced. Further, the above described two mutually contradicting requirements were satisfied with the provision of only a single detecting means, and therefore, cost was reduced.

As for the electrode material, as long as the electrodes 81, 82, and 83 are formed of electrically conductive substance, their functions remain similar to those described above. However, in this embodiment, nonmagnetic metallic substance, for example, nonmagnetic SUS, was used as the electrode material to prevent the electrodes from interfering with developer circulation.

Further, if the electrodes 81, 82, and 83 are directly attached to the frame portion 12, which constitutes the wall of the development chamber 9A, by deposition or printing, for example, or if they are built into the frame portion 12 with the use of two color molding along with electrically conductive resin, the number of problems resulting from the electrode attachment errors and electrode specification errors will be much smaller; in other words, they will be attached to the frame portion 12 with a higher degree of accuracy.

In the above, this embodiment was described with reference to the structure of the process cartridge in which the amount of magnetic developer

was continuously detected. However, this embodiment is also applicable to the structure of a developer container for containing nonmagnetic developer.

Next, referring to Figure 20, a developer amount detecting apparatus as an embodiment of the principle of the present invention will be described. Figure 20 is shows how the developer roller 9a and the first and second electrodes 81 and 82 within the process cartridge B are connected to a developer amount detection circuit 100 on the image forming apparatus main assembly side.

The first electrode 81 and development roller 9a are connected to a development bias circuit 101 as a development bias applying means through a first contact point 92 (contact point 17 on the apparatus main assembly side) and a second contact point 91 (contact point 19 on the apparatus main assembly side), respectively. Among the electrodes on the measuring side, the second electrode 82 or the output electrode is connected to a control circuit 102 through a third contact point 93 (contact point 18 on the main assembly side). The third electrode 83 is provided as an integral part of the second electrode 82 as described above, although it is not illustrated in the drawing.

The development bias circuit 101 is connected to a referential capacity member 88 of the control

circuit 102. A referential voltage V1 for detecting the developer remainder amount is set using an AC current I1 supplied from the development bias circuit 101.

The control circuit 102 sets the referential voltage V1 by adding a voltage drop V2 caused by the combination of an AC current I11 created by shunting the AC current I1 supplied to the referential capacity member 88, that is, an impedance element, at a volume VR1, and a resistor R2, to a voltage V3 set by resistors R3 and R4.

Therefore, an AC current I2 supplied to the first and second electrodes 81 and 82, or the electrodes on the measuring side, is inputted to an amplification circuit 103, from which it is outputted as a voltage V4 (V1 - 12 x R5), the value of which represents the developer remainder amount. In other words, the value of this output voltage is used as a value which represents the developer remainder amount.

According to the electrophotographic image forming apparatus in this embodiment, the developer amount between the first and second electrodes is continuously detected as described above, and the amount of the developer consumption is displayed on the basis of the detected information, so that a user can be prompted to prepare a brand-new process cartridge or a developer replenishment cartridge.

Further, the developer amount between the third electrode and developing member is detected, and the highly precise time at which developer depletion occurs is displayed on the basis of the detected information, so that a user can be prompted to replenish the process cartridge with developer. Incidentally, in this embodiment, the side from which voltage was applied comprised the development roller and first electrode, and the side from which signals were detected comprised the second and third electrodes. However, the same effects as those described above can be obtained even if the side from which voltage is applied comprises the development roller and second electrode, and the side from which signals are detected comprises the first and third electrodes.

It is difficult to designing a process cartridge in which a pair of electrically conductive members are positioned inside the developer container, because such a design affords only a small amount of latitude in terms of the location, shape, and size of the conductive members. However, such a design makes it possible to reduce the distance between the pair of electrodes to a level which the conventional structural arrangement cannot match. Further, such a design makes it possible to place the pair of electrically conductive members in the adjacencies of

the developing member, and therefore, it can improve the accuracy with which the threshold developer level below which images with abnormal white spots are formed is detected.

To describe the method for displaying the developer remainder amount, for example, there are a method in which the information detected by the above described developer amount detecting apparatus is directly displayed in the form of numerical value (for example, "10 %") on the screen 45 of a monitor of a personal computer 44 of a user as shown in Figure 21, or a methods illustrated in Figures 22(a) and 22(b). In the cases of the methods illustrated in Figures 22(a) and 22(b), a user is informed of the developer remainder amount by the point of a gauge 42 pointed by a hand 41 which moves in proportion to the developer amount. Also, a the electrophotographic image forming apparatus main assembly may be provided with an indicator section 43, which employs LEDs or the like which are turned on or off in a manner to reflect the developer amount.

<u>Embodiment 2</u>

Next, the second embodiment of the present invention will be described with reference to Figures 24 - 28.

The structure and functions of the electrophotographic image forming apparatus in this

embodiment are the same as those of the electrophotographic image forming apparatus in the first embodiment, and the components in this embodiment similar to those in the first embodiment are given the same referential codes as those given in the first embodiment. Further, the component arrangement in terms of the longitudinal direction, and the structure in the adjacencies of the electrodes, in this embodiment, which are the duplicates of those in the first embodiment, will not be described here.

Referring to Figure 24, in this embodiment, an electrode 84 is positioned on the bottom surface of the development chamber 9A. More specifically, the electrode 84 is placed in the path through which the developer T held in the developer container 11 is conveyed to the development roller 9a. Thus, hereinafter, this electrode 84 will be referred to as a developer path electrode. This developer path electrode 84 extends across the entire range of the developer path in terms of the longitudinal direction of the development roller 9a, and its cross sectional shape shown in Figure 24 is the same across its entire length.

In this embodiment, the development roller 9a is electrically connected to the development bias circuit 101 as shown in Figure 20 which was previously

referred to, and the developer path electrode 84 is connected to the control circuit 102 of the developer amount detection circuit 100.

The magnetic developer in the adjacencies of the bottom surface of the development chamber 9A is always under the influence of the magnetic force generated in the direction to attract the magnetic developer to the development roller 9a, by the magnet 9c in the development roller 9a. Therefore, there is a tendency that as the amount of the developer supplied to the development roller 9a decreases due to the reduction in the amount of the developer in the developer container 11, the developer in the adjacencies of the bottom surface of the development chamber 9A is consumed before the developer in the other parts of the development chamber 9A.

More specifically, referring to Figure 26, when the amount of the developer remaining in the developer container 11 is relatively large, the developer in the developer container 11 descends into the development chamber 9A due to the self-weight of the developer mass, and therefore, as the developer in the development chamber 9A is consumed as described above, the consumed developer is immediately replaced by the developer forced into the development chamber 9A due to the self-weight of the developer mass (Figure 26(a)). However, as the amount of the

developer remaining in the developer container 11 decreases, the force which forces developer into the development chamber 9A also decreases, failing to force the developer into the development chamber 9A by an amount equal to the amount of the developer consumed from the development chamber 9A. As a result, a cavity develops starting from the adjacencies of the bottom surface of the development chamber 9A (Figures 26(b) and 26(c)). Eventually, a state in which developer remains only around the longitudinal edge of the development blade 9d results (Figures 26(d)).

Since the developer in the process cartridge B is consumed as described above, the structural arrangement in this embodiment makes it possible to continuously detect the developer amount in the adjacencies of the bottom surface of the development chamber 9A.

The graph in Figure 27 shows typical changes in the electrostatic capacity which occurs as the developer remainder amount decreases. As is evident from Figure 27, even if the structural arrangement in this embodiment is employed, the developer remainder amount is continuously detectable. However, this structural arrangement is not as accurate as that in the first embodiment in terms of the detection of the threshold developer level below which images with

abnormal white spots are produced.

Thus, when it is necessary to increase the detection sensitivity to the threshold developer level, it is possible to employ an additional element such as the third electrode 83 in the first embodiment. However, in order to increase the sensitivity of the developer amount detecting apparatus, in the bottom portion of the development chamber 9A, a rod electrode 87 as an intermediary electrode, which extends across the entire longitudinal range of the development roller 9a, in parallel to the development roller 9a and developer path electrode 84, as shown in Figure 25, may be provided. With this arrangement, the developer path electrode 84 and rod electrode 87 serve as two electrodes of a condenser; in other words, the distance between the two electrodes of a condenser becomes smaller, increasing the detection sensitivity. More specifically, the intermediary electrode 87 is provided; the development roller 9a and third electrode 83 are equalized in potential level, and connected to the development bias circuit 101 as a development bias applying means; and the intermediary electrode 87 is connected to the control circuit 102 of the developer amount detection circuit 100. Therefore, the sensitivity with which the developer remainder amount is detected, and the sensitivity with

which the threshold developer level is detected, are raised without inviting drastic cost increase. Further, with this structural arrangement, the electrostatic capacity changes in response to the decrease in the developer remainder amount as indicated by the graph in Figure 28. The selection of the structural arrangement for a process cartridge B does not need to be limited to those described above. As a matter of fact, it does not matter where the electrodes are placed, as long as the sensitivity with which developer presence is detected can be improved.

Embodiment 3

Next, the third embodiment of the present invention will be described.

Also in this embodiment, an image forming apparatus which is similar in structure and function to the image forming apparatus in the first or second embodiments was employed. The components in this embodiment similar to those in the first and second embodiments will be given the same referential codes. Further, the component arrangement in terms of the longitudinal direction of the process cartridge, the structures in the adjacencies of the electrodes, and the like, which are identical to those in the first and second embodiments, will not be described.

According to the arrangement in this embodiment, the developer remainder amount can be

detected much more accurately than in the first and second embodiments.

As one of the methods for improving detection accuracy, it is possible to increase detection sensitivity. However, it is difficult to substantially increase the sensitivity by simply making a few changes to the shapes and positioning of the electrodes, based on the structures in the first and second embodiments.

Thus, in this embodiment, the structural arrangement in the first embodiment, in other words, the structure having the first, second, and third electrodes 31, 32, and 83 as illustrated in Figure 19, and the structural arrangement in the second embodiment, in other words, the structure in which the developer path electrode 84 was placed on the bottom surface of the developer chamber 9A as illustrated in Figure 24, were employed in combination as shown in Figure 29.

With regard to the threshold developer level detection, a sufficient level of detection accuracy was achieved by the condenser portion constituted of a combination of the third electrode 83 and development roller 9a in the first embodiment, and therefore, the intermediary electrode 87 was not employed in this embodiment. However, employing the intermediary electrode 87 depending on circumstances does not cause

any problem, and will provide the same effects as those provided by this embodiment.

With the provision of the above described structural arrangement, the detection sensitivity increases by a large margin, and therefore, the developer remainder amount can be continuously detected with greater accuracy. Further, the area in which the developer remainder amount can be detected extends across the entire range of the development chamber 9A in terms of its longitudinal direction, and therefore, even if the state of the developer mass in the developer container 11 temporarily changes due to circumstances, for example, because a process cartridge is taken out of the image forming apparatus main assembly and is shaken, the developer remainder amount detected after such a temporary change rarely deviates from the developer remainder amount detected prior to such a change.

In this embodiment, the development roller 9a and first electrode 81 are equalized in electrical potential, and are connected to the development bias circuit 101, whereas the second electrode 82 and developer path electrode 84 are equalized in electrical potential level and are connected to the control circuit 102 of the developer amount detection circuit 100.

How these electrodes or their equivalents are

connected in terms of circuit design does not need to be exactly as described above; it does not matter as long as their connection realizes a high level of detection sensitivity, in particular, in the adjacencies of the bottom surface of the development chamber, and also in the adjacencies of the first and second electrodes 81 and 82.

Also regarding the connection of the electrodes, cost increase can be avoided by equalizing, in electrical potential level, the electrodes which are to be equalized in electrical potential level, by connecting them to each other, because such an arrangement does not increase the number of contact points between these electrodes and the power source on the main assembly side.

Figures 30(a) and 30(b) show the relationships between the changes in the developer amount, and the changes in the electrostatic capacity which occurred in response to the changes in the developer amount, in the first and second embodiments, respectively. Figure 30(c) shows a typical relationship between the changes in the developer amount, and the changes in the electrostatic capacity which occurred in response to the change in the developer amount, when the structure in this embodiment was employed.

It is evident from these graphs that the

developer remainder amount can be also accurately detected with the use of the structure in this embodiment.

Also in this embodiment, a flat piece of electrically conductive material was employed as the developer path electrode 84, and was fixed to the internal surface of the container wall. However, the configuration of the developer path electrode 84 does not need to be limited to the one employed in this embodiment. For example, the developer electrode 84 may be fixed to the external surface of the container wall, or it may be fixed in a manner to hold a certain distance from the container wall. Further, it may comprise a plurality of electrically conductive rods placed in parallel. In other words, as long as it is placed across the path through which developer is conveyed to the developing member by the developer stirring-conveying member, it is possible to obtain the same effects as those obtained with the use of the structural arrangement in this embodiment.

Incidentally, in the above described embodiments, the developer remainder amount can be continuously detected while the developer remainder amount is in a range from approximately 30 % down to 0 %, assuming that the developer container is 100 % full prior to its initial usage of a process cartridge. However, the present invention is not limited by this

arrangement. In other words, the range in which the developer remainder amount in the container can be continuously detected may be set to a range from 50 % down to 0 % or a range from 40 % down to 0 %, for example. Here, an indication that the developer remainder amount is 0 % does not means that the developer has been completely depleted. It also includes such a condition that the developer amount in the container has decreased to a level below which an image with a predetermined level of quality can not be obtained.

As is evident from the above description of the embodiments of the present invention, according to the present invention, the developer amount can be continuously detected with a high level of accuracy, and therefore, usability can be improved.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth, and this application is intended to cover such modifications or changes as may come within the purposes of the improvements or the scope of the following claims.